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A DISCUSSION OF DEFICIENCIES IN BALLISTIC WINDS AS PRESENTLY COMPUTED FOR ROCKET-ASSISTED PROJECTILES

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I. INTRODUCTION

In order to allow for the effect of wind on the trajectory of Rocket-Assisted Projectiles (RAP) fired from the 5"-38 cal. gun, weighting factors have been determined and provided by the Naval Weapons Laboratory, Dahlgren. These weighting factors were derived by introducing different wind structures into computations carried out with a computer program which serves to model the RAP trajectroy. The difference between offsets of impacts for various wind structures were then resolved into weighting factors under assumptions which are equivalent to the following:

1. Assumed: that the trajectory computer program does in fact yield a valid representation of the offset resulting from the wind at various altitudes.

2. Assumed: that for practical purposes, the offset of impact from a "no-wind" impact point can be derived from the mean wind in successive layers of the atmosphere, or in successive altitude zones.

3. Assumed: that for practical purposes, offset can be derived with the further simplifications:

   a. That the effect on range can be determined solely in terms of the wind components along the line of fire.

   b. That the displacement perpendicular to the line of fire is determined solely by the wind components perpendicular to the line of fire.

   c. There is an underlying assumption, that weighting factors compatible with assumptions 3.a. and 3.b. have been derived in a proper and satisfactory manner.

Granting the first two assumptions, a test or experiment was designed to assess the third. The reasons for questioning the third assumption are given below:

For conventional gunfire, the effect of wind components across the line of fire does not greatly affect the range of a shot, particularly when shooting at targets appreciably closer than maximum range. Similarly, wind components along the line of fire have little effect upon the lateral displacement of the shot. Therefore, considering other contributions to the accuracy or inaccuracy of precomputing offset due to wind, it is convenient and is accepted as practical to compute variation of range as purely a function of the component of wind along the line of fire. Similarly, the lateral deflection of a shot is computed as purely a function of the wind components perpendicular to the line of fire. (In fact, conventional ballistic winds are most frequently computed with identical weighting factors for both effects.)

The rocket-assisted projectile differs from the conventional projectile. This difference lies primarily in that its propellent is not all expended within the gun, but after traversing a goodly depth of atmosphere. Therefore, if the wind structure of the atmosphere traversed can affect the pitch or yaw of the projectile prior to burnout, part of the energy of the remaining propellant will be expended in increasing the projectile's departure from the "no-wind" trajectory. Even effects which would be negligible for the conventional projectile might then be of importance for RAP.

Specifically, then, it becomes of interest to determine whether the wind component perpendicular to the line of fire, or vertical variations thereof, can in fact affect the range; and whether the component of wind along the line of fire, or variations thereof with altitude, can in fact affect the lateral displacement of the point of impact.

Perusal of the weighting factors presently available for RAP ballistic wind computations, together with speculation upon the trajectory effects which they represent, have lead to the selection of a few simple wind structures with which to perform a test. The test is in no sense exhaustive; however, it does indicate that under certain realistic meteorological conditions, the exclusion of the cross wind when computing range corrections could lead to significant errors.

II. THE TEST

To validate assumption 1., NWL Dalgren was requested to provide "computed trajectories", using the same computer program that was used in the process of deriving the currently published weighting factors.

The second assumption (generally quite valid for all practical problems) is fulfilled in this experiment by having all computer trajectories fired at the same elevation angle, with wind input varying with height at one zonal boundary.

The third assumption, i.e., that range-wind and cross-wind components are independent, as well as the method of deriving the weighting factors under these assumptions, is the subject of the test described herein.

All computations were made for the same ballistic density and the same elevation angle, so that the simple change of wind with height should be the only variation between successive computations. In all instances the wind component in the line of fire was assumed constant. For example, the weapon was assumed to be fired northward with a wind component from the south of 20 knots at all altitudes. (This could represent any other vertical variation of the north-south component of the wind which would yield a ballistic range-wind component of identical magnitude, provided that the east-west component had no effect on the range when shooting toward the north.)

The introduction of wind across the line of fire in conjunction with wind along the line of fire is the fundamental

aspect of this test. The manner of introduction represents a turning and strengthening of the wind with height.

In the lowest 6 kilometers, the cross-wind component is held null. Above 6000 meters, successively larger wind components were introduced across the line of fire. These represent successive degrees of turning and strengthening of the wind in the upper portions of the flight. (Again, if assumption 3.b. held, the upper wind for any one instance could be interpreted as representing any wind structure for which the cumulative product of cross-range weighting factor and cross-range wind would be of the same value.)

III. RESULTS

The results of these computations are shown in table 1. In line A of the table, with no lateral wind, there is no lateral deflection; nor was such a deflection expected in terms of ballistic wind. The range exceeds that of a "no-wind" shot by 1013 yards, which is in good agreement with a figure of 1022 yards computed by means of ballistic wind for a shot with maximum ordinate of 10 kilometers and a following wind of 20 knots.

The shots represented on subsequent lines of table 1 have no change in the following wind component at all levels. They have, however, cross-range winds as indicated in columns 1 and 2. The lateral offset is shown in column 3, where it is indicated as negative -- meaning that the impact point is "upwind" of the zero cross-wind impact. In ballistic wind computations, similar results are brought about by means of the negative weighting factors used for certain zones. The magnitude of the lateral offsets (column 3) are in fairly good agreement with the expectations from ballistic wind computations shown in column 4 (see difference in column 5). Although a refined ballistic wind might be computed with higher order terms, giving more exact expectations, the additional precision gained is not significant for this test.

The ranges for the several shots actually computed are shown in column 6. The departures of these ranges from that of no-wind shot "A" are shown in column 7. It is this column

Table 1

	1	2	3	4	5	6	7	8
ROW or "SHOT"	WIND PERPENDICULAR TO LINE OF FIRE BELOW 6 km.	ABOVE 6 km.	LATERAL DEFLECTION OF TRAJECTORY by TRAJECTORY COMPUTATION	by BALLISTIC WIND COMPUTATION	COL 4 minus COL 3	RANGE	RANGE minus RANGE of "SHOT A"	CONSTANT times sq. of wind in COL 2
A	0 Kts.	0 Kts.	0 Yds.	0 Yds.	0 Yds.	28,541 Yd.	0 Yd.	0 Yd.
B	0	20	-229	-216	13	28,518	-23	22.5
C	0	40	-452	-432	20	28,449	-92	90
D	0	80	-863	-864	-1	28,180	-361	360
E	(0)	(100)						(562.5)
F	(0)	(120)						(810.0)
G	(0)	(140)						(1102.5)
H	(0)	(160)						(1440.0)

which brings to light the fact that the range is not independent of the wind component across the line of fire. Even though the ballistic wind along the line of fire is the same for all these shots, the departures of these ranges from that expected varies approximately with the square of the cross wind encountered. This can be seen by reference to the last column, in which the entry is proportional to the square of the cross-range component of the wind.

Initially, only shots A, B, C and D were requested of the Naval Weapons Laboratory, Dahlgren. However, the departures illustrated by these shots are well fit by a simple parabolic formula. It was therefore decided that the illustration could be extended by extrapolating shots E, F, G and H, and that for purposes of this test it would not be necessary to request additional computer computations. Such extrapolations are shown in parentheses for cross-range winds up to 160 knots.

IV. CONCLUSIONS

A. It appears from table 1 that rocket-assisted projectiles would impact far short of the point determined by means of current ballistic wind computations under certain naturally occurring circumstances. The particular circumstances brought to light by this study occur whenever the following situations exist simultaneously:

1. Fire is directed to ranges well beyond the range of conventional 5" shells (the reason for using RAP)

2. The winds show a marked difference between the upper and lower zones, and are not cooperatively lined up with the direction of fire. This may frequently occur when an essentially north or south wind predominates in the lower levels and a westerly wind component is markedly present aloft. With a jet stream present or nearby, winds in the upper zone would be strong.

B. Departures of the size shown in these example shots are judged to be significant. Accordingly, a procedure is required which considers the effect of cross-range wind on range, and possibly of along-range wind on lateral offset. The wind structures assumed in deriving the procedure should include various strong instances of wind increase and turning in the higher zones.

(Note - It can not be assumed that the constant of proportionality used for the last column of table 1 would apply for all directions of fire, or for other values of maximum ordinate, or for wind shifts at other than 6 kilometers.)

Ballistic computations for practical applications would be more cumbersome if the procedure includes terms or weighting factors for the effect of cross-range wind components on range, and range-wind components on lateral offset. This would make hand computations tedious if not impractical; but would present no difficulty to computation by computer, once such terms are included in the RAP ballistic wind computer program.